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DIVISION 2

THE INFLUENCE OF IMPACT VELOCITY ON THE TENSILE PROPERTIES OF FOUR MAGNESIUM ALLOYS AND 24S ALUMINUM ALLOY

by

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Preface

The work described in this report is pertinent to the projects designated by the Navy Department Liaison Officer as NO-11 and NS-109 and to Division 2 project P2-303.

This work was carried out and reported by the California Institute of Technology under Contract OEMsr-348.

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this report and prepared it for duplication.

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THE INFLUENCE OF IMPACT VELOCITY ON THE TENSILE PROPERTIES OF FOUR MAGNESIUM ALLOYS AND 24S ALUMINUM ALLOY

Abstract

This report presents the results of further investigations of the influence of impact velocity on the tensile properties of metals and alloys. Part I presents the results of tests on four magnesium alloys, namely, Dow Metal FS-1-HTA, J-1-HTA, M-HTA and O-1-HTA. It is concluded that alloys M and O are susceptible to embrittlement by stress concentration. The energy per unit volume required to fracture these two alloys dynamically was about the same as statically when a fillet of 5 in. radius was used. The energy to fracture alloys F and J in specimens with 1/16 in. radius fillet is higher dynamically than statically. The critical velocity of each of the four alloys is greater than 200 ft/sec.

Part II presents the results of static and dynamic tensile tests on a 24S aluminum alloy in the "T" and annealed conditions. The tensile properties of this alloy in both structural conditions are larger dynamically than statically. As may be expected, the values of these properties are lower for the annealed alloy. The critical velocity is greater than 200 ft/sec for both structures. These results are compared with those of a 17ST aluminum alloy previously reported with the conclusion that in general there is no appreciable difference between the dynamic properties of the 17ST alloy and the 24ST alloy although the 17ST may be slightly superior.

PART I. THE INFLUENCE OF VELOCITY ON THE TENSILE PROPERTIES OF FOUR MAGNESIUM ALLOYS

1. Introduction

Static and dynamic tensile tests have been made on four magnesium alloys as an extension of previous work[1,2,3] in which the influence of impact velocity on the tensile properties of metals was studied.

1/ P. E. Duwez, D. S. Clark and D. S. Wood, The influence of impact velocity on the tensile properties of plain carbon steels and of a cast-steel armor plate, NDRC Report A-154 (OSRD No. 1274), Mar. 1943.

2/ P. E. Duwez, D. S. Wood and D. S. Clark, Dynamic tests of the tensile properties of SAE 1020 steels, Armco iron and 17ST aluminum alloy, NDRC Report A-182 (OSRD No. 1490), May 1943.

3/ P. E. Duwez, D. S. Wood and D. S. Clark, The influence of impact velocity on the tensile properties of class B armor plate, heat-treated alloy steels and stainless steel, NDRC Report A-195 (OSRD No. 1641), July 1943.

2. Materials tested

The materials for these tests were obtained through the courtesy of the Dow Chemical Company and were tested as received. In this report, the various alloys will be designated by the letters F, J, M and O. The results of a chemical analysis made by the Smith-Emery Company of Los Angeles are given in Table I. Photomicrographs are shown in Figs. 1 and 2.

Table I. Designations and chemical analyses of magnesium alloys.

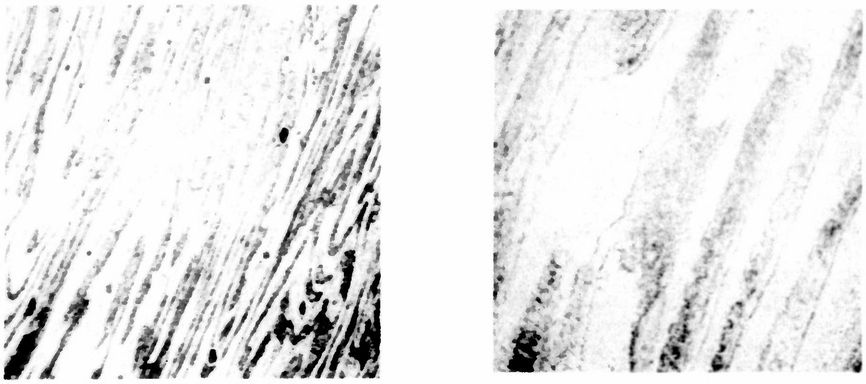
Dow Designation	Dow Alloy No.	Dow Extrusion No.	Project Designation	Chemical Analysis Constituents (percent)			
				Mn	Si	Al	Zn
FS-1-HTA	27728	10682	F	0.42	0.08	1.16	—
J-1-HTA	27729	10686	J	0.22	.04	3.39	0.13
M-HTA	27730	10688	M	1.61	.05	0.09	—
O-1-HTA	27731	—	O	0.32	.04	3.12	0.03

Specimens of each alloy were machined from rods $\frac{1}{2}$ in. in diameter to the dimensions shown for type A in Fig. 3. This is the standard specimen that has been used in all previous investigations of this project. Alloys M and O were found to be sensitive to stress concentration, this made it desirable to repeat the tests with specimens of larger fillets as shown for type B in Fig. 3.

3. Testing procedure

The static tensile tests were made with a universal testing machine in the usual manner. The dynamic tensile tests were made with equipment consisting of a rotating wheel 44 in. in diameter which has been described in detail in an earlier report.[4/] In the dynamic tests, the force-time diagrams at the fixed end of the specimens were recorded for impact velocities ranging from 25 to 200 ft/sec. From these data, the total

4/ P. E. Duwez, D. S. Wood, D. S. Clark, The propagation of plastic strain in tension, NDRC Report No. A-99 (OSRD No. 931), Oct. 1942.



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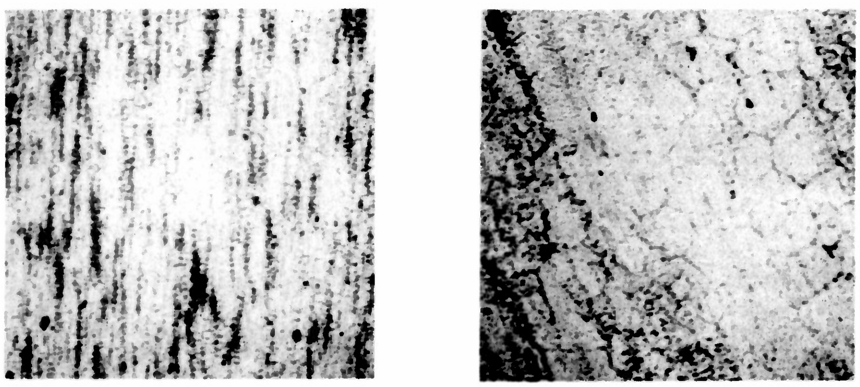
Alloy F, etched with malic acid.



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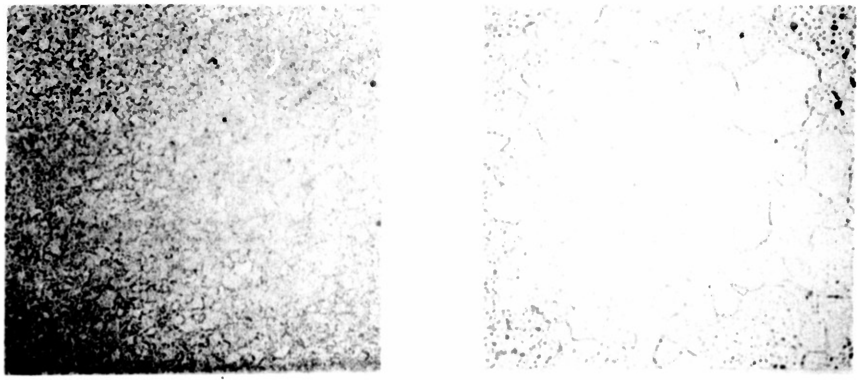
Alloy J, etched with tartaric acid.

Fig. 1. Photomicrographs of magnesium alloys F and J.



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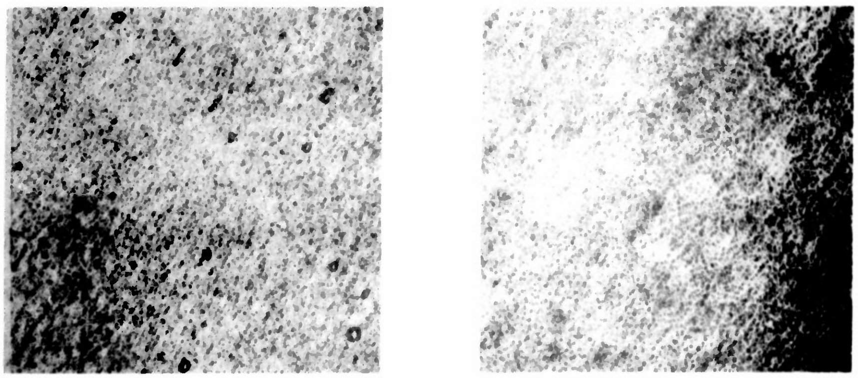
Alloy M, etched with tartaric acid.



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Alloy O, etched with tartaric acid.

Fig. 2. Photomicrographs of magnesium alloys M and O.

energy required to rupture the specimen was determined by integrating the force-time diagram and multiplying by the impact velocity. The energy per unit volume required to rupture the specimen was obtained by dividing the total energy by the volume of the specimen included in the gage length (the distance between shoulders). In the case of the type B specimen, the results of this procedure are not quite accurate, since the strain in the long fillets is not as great as in the cylindrical section of the specimen. However, since those alloys for which the type B (long fillet) specimens were used were susceptible to embrittlement from marks that might have been used as gage points, no marks could be made. While the method of including the entire gage length seemed to be the only satisfactory procedure, it should be remembered that the actual energy absorbed per unit volume is somewhat greater than reported. Measurements of hardness, total elongation and reduction of area were also made on each specimen. The reliability of dynamic energy measurements and the influence of specimen shape and size on the results obtained in tensile impact tests have been discussed in previous reports.[5,6]

4. Discussion of results

The results of the static tests on these alloys are given in Table II. The type A specimen was used in making four static tests on each of the alloys F, J and M, and two tests on alloy O. The type B specimen was used in making two static tests on each of the alloys M and O. Static stress-strain curves for each alloy are presented in Figs. 4 and 5. In making the static tests on type A specimens of alloys F and J, the fracture occurred in the central portion of the gage length with appreciable reduction of area. In the tests on alloys M and O with the same type of

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5/ P. E. Duwez, D. S. Clark, D. S. Wood, Discussion of energy measurements in tension impact tests at the California Institute of Technology, NDRC Report No. A-217 (OSRD No. 1829), Sept. 1943.

6/ D. S. Wood, P. E. Duwez and D. S. Clark, The influence of dimension and shape on the results of tensile impact tests, NDRC Report A-237 (OSRD No. 3028), Dec. 1943.

Table II. Results of static tests on magnesium alloys.

Metal	Bar No.	Specimen No.	Ultimate Strength (lb/in²)	Proportional Limit (lb/in²)	Energy per Unit Volume (ft lb/in³)	Elongation in 8 in. (percent)	Reduction of Area (percent)	Hardness Rockwell	Theoretical Critical Velocity (ft/sec)	Experimental Critical Velocity (ft/sec)
Specimens, type A (fillet radius 1/16 in.)										
F	1 B	1	35500	26000	265	9.0	22	13.6A	230	
F	1 B	2	35400	25000	258	8.8	25	16.5A	243	>200
F	1 B	3	36600	26000	222	7.4	25	13.0A	235	
F	1 B	4	36200	25000	237	8.0	23	14.6A	223	
J	1	1	43000	28500	321	9.4	15	16.5A	308	
J	1	2	43200	29500	313	9.1	15	15.4A	301	>200
J	1	3	44200	30000	329	9.3	22	14.2A	295	
J	1	4	44700	31500	394	10.8	24	14.9A	310	
M	1	1	26300	16500	141	6.7	7	41.7F	226	
M	1	2	25400	17000	125	5.9	8	44.5F	204	
M	1	3	26200	18000	121	5.7	6	43.7F	201	Brittle
M	1	4	26500	17500	128	5.8	6	45.2F	205	
O	1 C	16	48500	30000	160	3.9	6	43.0B	263	Brittle
O	1 C	17	52300	31000	164	3.8	5	43.5B	263	
Specimens type B (fillet radius 5 in.)										
M	6	15	30000	20000	265	11.8	15	44.3 F	263	>200
M	6	16	31000	20500	263	11.2	12	42.7 F	261	
O	7 B	1	49500	29500	134	3.0	7	45.2 B	241	>200
O	7 B	2	51000	33000	129	2.9	7	46.1 B	237	

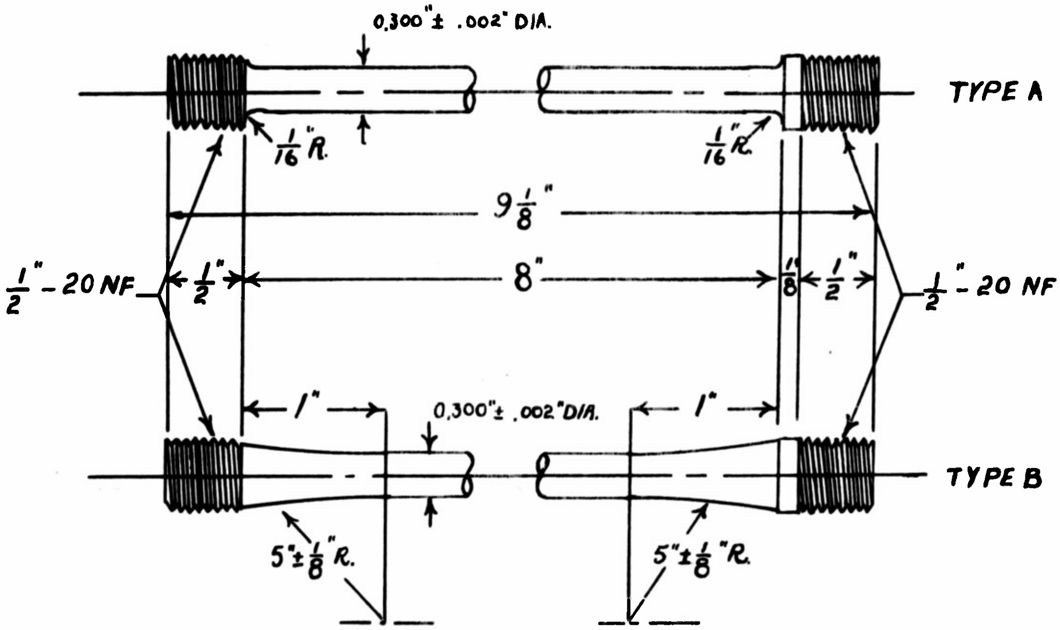

Fig. 3. Tensile specimens.

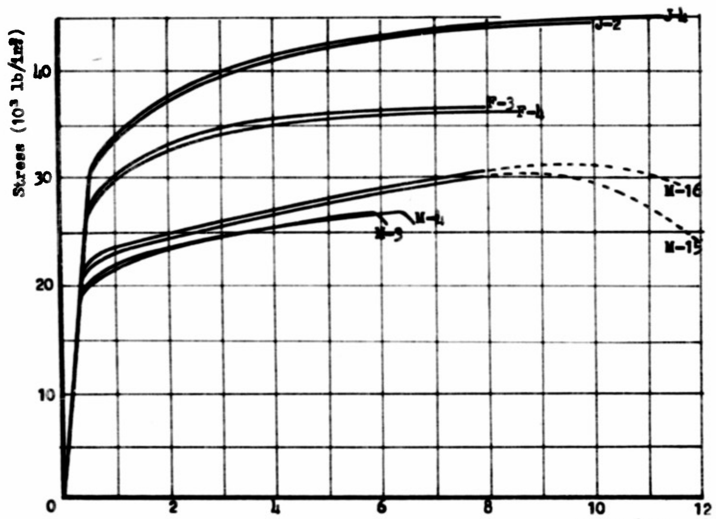

Fig. 4. Static stress-strain curves for magnesium alloys F, J and M. All specimens are type A, except M-15 and M-16, which are type B.

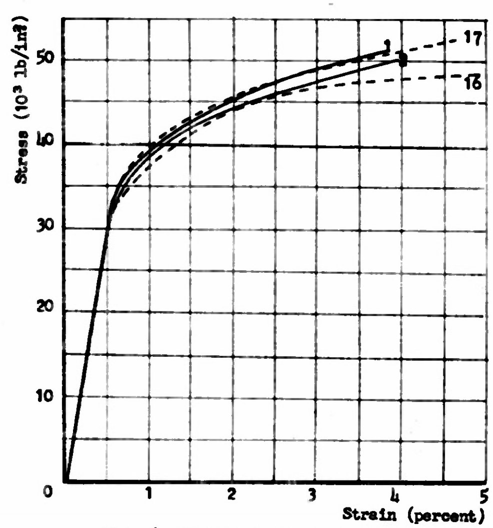

Fig. 5. Static stress-strain curves for magnesium alloy O; specimens No. 16 and No. 17, type A specimens, specimens No. 1 and No. 2, type B specimens.

specimen, the fracture occurred at the base of the fillet with small reduction of area.

As a result of this experience, two static tests were made on alloys M and O with the type B specimen. The results shown in Table II indicate the marked susceptibility of alloy M to stress concentration. When using the large fillet, failure occurred within the uniform section of the specimen and gave rise to a slightly higher proportional limit and ultimate strength and a very marked increase of percentage elongation for the M alloy. The results of the tests with type A specimen of alloy O gave some indication of a similar sensitivity to stress concentration. However, the use of larger fillets did not materially alter the results even though fracture occurred within the gage length.

The latter part of the stress-strain diagrams of alloy M made with type B specimens 15 and 16, shown in Fig. 4, indicate a progressive decrease in the stress, as if necking were taking place. The recorded values of stress and strain in this part of these tests were scattered and the dotted portion of the curves have been drawn as an approximation. When the maximum load was reached in the static tests on this material, cracks developed in the specimens. These cracks were responsible for the observed sudden change of load. The percentage elongation listed in Table II was measured after the test and includes the plastic permanent strain in the specimens and the distances corresponding to the opening of the cracks. If the specimens had failed when the first crack appeared, they would have had a percentage elongation of about 8 percent. This observation will be considered in the discussion of the results of the dynamic tests.

In comparing the static properties of the magnesium alloys the results of the tests with type A specimens of alloys F and J and type B specimens of alloys M and O are used. The ultimate strength and the proportional limit decrease following the order O, J, F and M. The percentage elongation in 8 in. increases following the same order. The energy absorbed per unit volume is greatest for J, intermediate for alloys F and M and is lowest for alloy O.

The results of the dynamic tensile tests on these alloys are given in Tables III, IV and V. The curves of ultimate strength, percentage elongation and energy per unit volume required to rupture, each versus impact velocity, are given in Figs. 6 and 7. The ultimate strength of

Table III. Results of dynamic tensile tests on magnesium alloys F and J using type A specimen.

Specimen No.	Bar No.	Impact Velocity (ft/sec)	Ultimate Strength (lb/in^2)	Energy per Unit Volume (ft lb/in^3)	Elongation in 8 in. (percent)	Reduction of Area (percent)	Hardness Rockwell A
			Alloy F				
5	1 B	25.4	48400	285	7.6	28	13.6
6	1 B	49.7	50600	370	9.1	33	15.9
14	1	75.1	56000	420	9.3	24	15.5
7	1	75.2	50200	300	7.6	24	14.9
15	1	98.8	52100	460	10.8	34	15.0
8	1	105.0	50000	452	11.7	31	14.9
9	1	125.2	51300	420	10.5	35	16.0
10	1	150.5	53000	468	10.8	24	14.6
12	1	175.0	51800	420	9.6	47	14.2
13	1	197.3	54200	350	8.8	27	17.3
						Average	15.0
			Alloy J				
5	1	25.2	45300	306	8.7	34	15.0
6	1	49.7	52500	480	11.5	22	16.9
13	1 B	50.0	49500	405	10.1	24	15.4
7	1	75.1	52800	455	10.8	45	15.5
8	1	100.0	52400	510	11.5	41	12.5
9	1	125.5	53300	515	12.0	35 & 55**	12.4
10	1	151.0	52300	470	11.0	39	15.0
15	1 B	175.3	52500	502	12.1	24	16.6
11	1 B	175.4	53400	425	9.8	23	14.2
12*	1 B	200.0	50000	198	5.0	17	15.8
14	1 B	200.0	51000	460	11.2	18	14.7
						Average	15.0

*Results not considered for average given in Table VI.

**Double rupture.

Table IV. Results of dynamic tensile tests on magnesium alloy M.

Specimen No.	Bar No.	Impact Velocity (ft/sec)	Ultimate Strength (lb/in^2)	Energy per Unit Volume ($ft\ lb/in^3$)	Elongation in 8 in. (percent)	Reduction of Area (percent)	Hardness Rockwell F
Type A specimens							
14	1	10.5	35700	11	0.5	7	44.3
15	2	20.7	39900	12	0.4	1	39.0
5	1	25.4	39300	56	2.1	5	42.9
6	1	51.9	39000	55	1.7	6	43.2
7	1	75.0	39000	50	1.8	5	43.2
8	1	99.8	39500	50	1.8	4	43.4
10	1	124.7	34000	10	0.4	3	43.8
12	1	125.5	34500	—	0.1	3	42.5
11	1	149.5	35800	5	0.2	4	42.1
13	1	149.5	39000	62	2.0	10	45.2
						Average	43.0
Type B specimens							
10	6	25.0	48000	248	7.0	17	41.9
1	6	25.0	47000	236	6.8	13	43.5
11	6	50.1	47500	160	5.2	14	39.8
2	6	50.4	45000	238	6.7	13	44.3
12	6	74.7	48500	262	7.4	15	41.2
3	6	74.9	47500	258	7.4	10	41.6
4	6	102.3	44700	276	8.3	12	47.1
13	6	103.7	46500	236	7.0	6 & 8*	42.9
5	6	127.6	47600	287	7.7	12	44.5
14	6	127.7	45600	234	7.1	13	45.1
6	6	149.0	48000	292	7.7	10 & 16*	43.4
7	6	175.0	48000	250	6.3	4	39.6
9	6	199.0	48500	240	6.6	5 & 15*	45.2
						Average	43.5

*Double rupture.

Table V. Results of dynamic tensile tests on magnesium alloy O.

Specimen No.	Bar No.	Impact Velocity (ft/sec)	Ultimate Strength (lb/in^2)	Energy per Unit Volume (ft lb/in^3)	Elongation in 8 in. (percent)	Reduction of Area (percent)	Hardness Rockwell B
Type A specimens							
11	1 B	10.2	----	----	0.2	3	45.7
12	1 B	14.5	58 000	----	.5	3	45.3
13	1 C	20.5	57 500	----	.4	4	48.6
3	1 A	25.7	59 500	----	.1	8	43.0
4	1 A	49.9	58 600	70	1.6	8 & 10*	43.5
9	1 B	49.9	61 500	----	0.1	4	39.8
5	1 A	75.1	59 100	----	.2	9	40.0
6	1 A	99.8	61 300	----	.7	21	41.2
10	1 B	100.0	59 600	20	.5	4 & 6*	46.3
7	1 B	126.0	60 100	----	.1	0	43.2
8	1 B	150.2	60 800	----	.1	4	44.1
						Average	43.7
Type B specimens							
1	2 A	26.2	65 000	212	4.2	8	46.6
10	1 D	49.5	72 000	222	3.8	0	45.6
3	2 A	76.0	64 000	170	3.2	6	44.4
4	2 A	102.0	66 000	150	2.7	3	46.0
5	2 A	125.0	----	----	1.7	0	45.2
6	2 A	128.0	68 000	----	1.8	0	46.7
7	1 D	152.0	----	----	2.1	12	46.3
8	1 D	179.0	68 000	----	1.5	0	42.0
9	1 D	200.0	66 400	177	2.5	0 & 9*	47.0
						Average	45.5

*Double rupture.

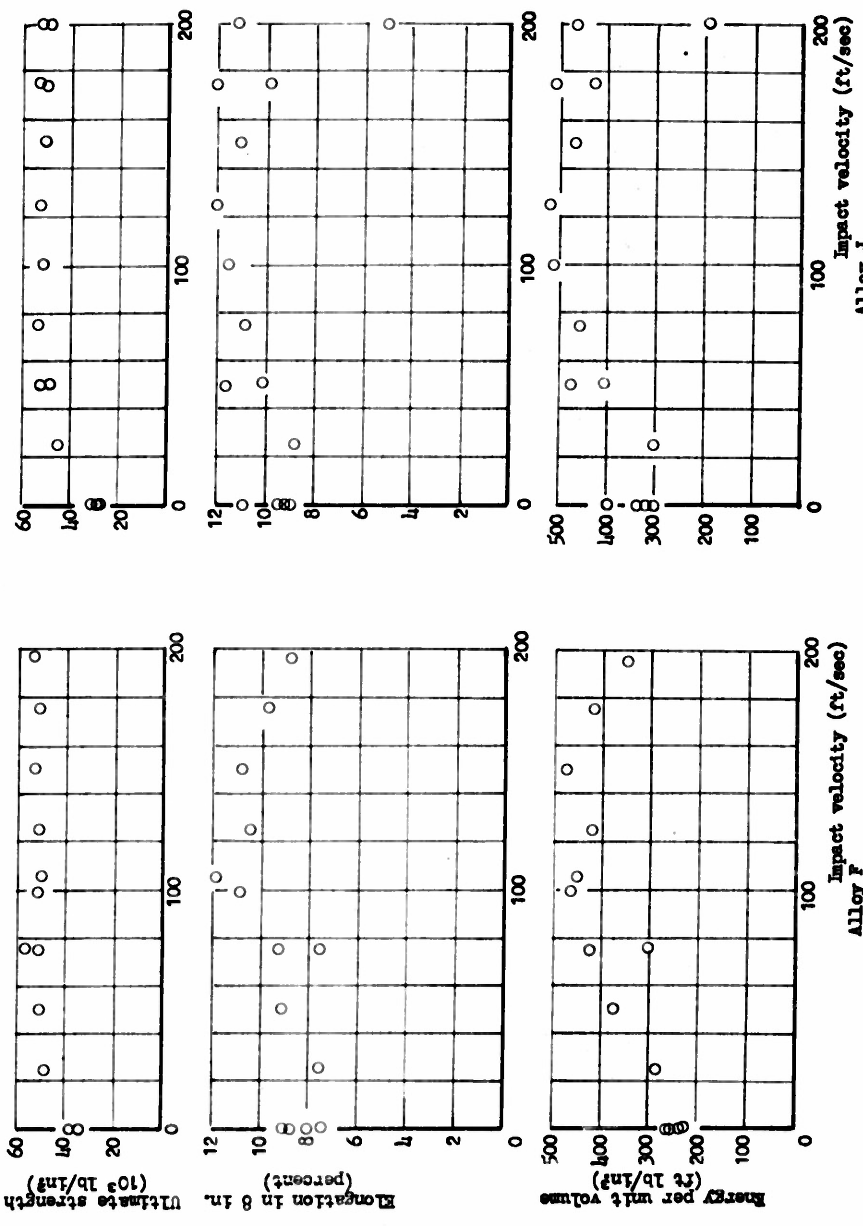

Fig. 6. Ultimate strength, percentage elongation, and specific energy, each versus impact velocity, for magnesium alloys; type A specimens.

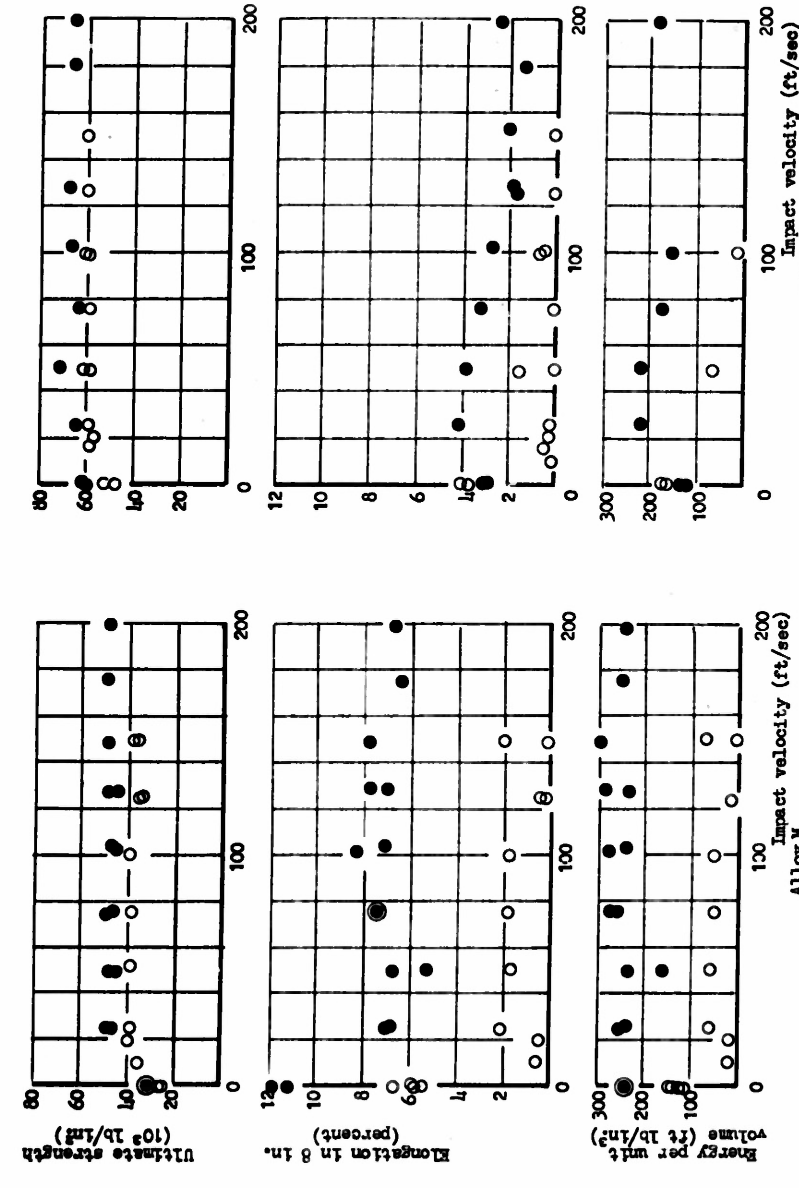

Fig. 7. Ultimate strength, percentage elongation, and specific energy, each versus impact velocity, for magnesium alloys; O, type A specimens; ●, type B specimens.

all four alloys is increased slightly under dynamic conditions. The percentage elongation and energy absorption are increased slightly for alloys F and J. However, with the type A specimens of alloys M and O, the elongation and energy decrease markedly under dynamic conditions. The dynamic tests with the type B specimens gave results of the character more commonly obtained. The elongation observed in tests on alloy M with type B specimens is not quite correct since the full length of the specimen between shoulders was considered. Therefore the correct value of elongation should be somewhat higher than that reported. None of the dynamic specimens exhibited cracks such as were observed in the static tests. In discussing the results of the static tests it was indicated that the probable correct elongation was about 8 percent. Therefore the decrease of elongation observed in Fig. 7 or the difference between the static and average dynamic elongations is misleading. In the true sense in the absence of stress concentration the elongation is not markedly changed by increasing impact velocity within the range considered.

There is no indication of a critical velocity for any of these alloys below 200 ft/sec. In making this statement, no credence is given to the one low value of elongation and energy obtained with alloy J at an impact velocity of 200 ft/sec. This malalignment of data is probably the result of a particular specimen condition. All the values of critical velocity computed by the von Kármán relations[7/] are above 200 ft/sec.

The averages of the static and of the dynamic tensile properties of these alloys are given in Table VI, and are compared graphically in Fig. 8. From this table these facts are apparent: the increase in ultimate strength resulting from dynamic loading varies from 17 percent to 54 percent for the four alloys; the percentage elongation is increased under dynamic conditions for all alloys except M, for which an apparent decrease of 39 percent is observed. In the case of alloy M, it should be remembered that, because of the presence of cracks in the specimens before rupture, the percentage

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7/ Th. von Kármán, On the propagation of plastic deformation in solids, NDRC Report No. A-29 (OSRD No. 365), Jan. 1942.

Table VI. Comparison between average static and average dynamic values for magnesium alloys.

Type of Specimen	Alloy Designation	Average Hardness Rockwell	Static Proportional Limit (lb/in²)	Ultimate Strength Average Value (lb/in²) Static	Ultimate Strength Average Value (lb/in²) Dynamic	Ultimate Strength Increase (percent)	Elongation in 8 in. Average Value (percent) Static	Elongation in 8 in. Average Value (percent) Dynamic	Elongation in 8 in. Increase (percent)	Energy per Unit Volume Average Value (ft lb/in³) Static	Energy per Unit Volume Average Value (ft lb/in³) Dynamic	Energy per Unit Volume Increase (percent)	Reduction of Area Average Value (percent) Static	Reduction of Area Average Value (percent) Dynamic
A	F	15.0A	25500	35920	51760	44	8.3	9.6	16	245	394	38	24	31
A	J	15.0A	29870	43750	51360	17	9.6	10.9	13	339	454	34	19	33
A	M	43.0F	17250	26100	37570	44	6.0	1.1	--	129	0+	--	8	5
B	M	43.5F	20250	30500	47100	54	11.5	7.0	-39**	264	244	Appr.0	13	11
A	O	43.7B	30500	50400	59600	18	3.8	0.4	--	162	0+	--	4	7
B	O	45.5B	31250	50250	67000	33	2.9	3.3*	13	132	187	42	7	4

*Average of specimens for which the energy could be measured.

**Correct value should probably be about zero -- see text for explanation.

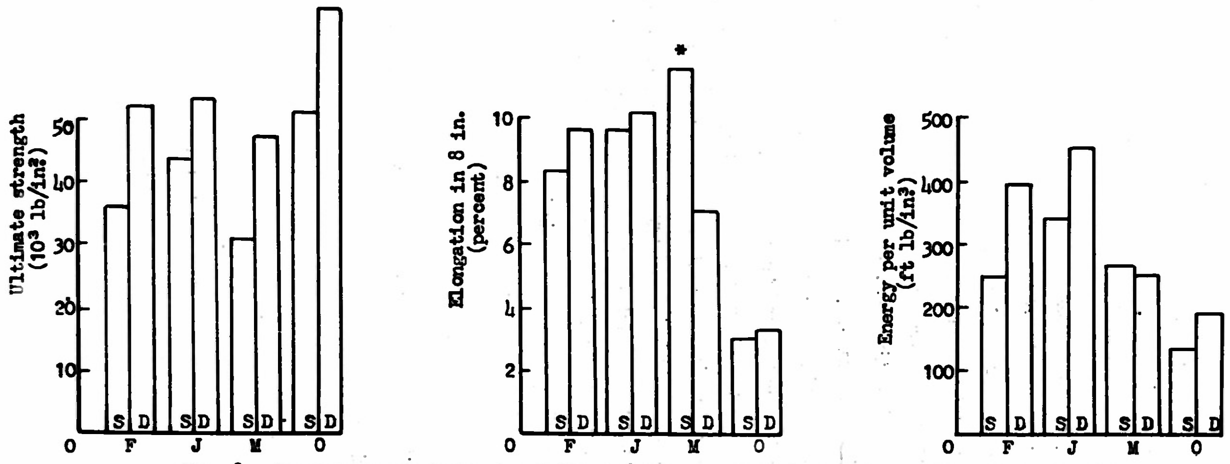


Fig. 8. Comparison of static S and dynamic D properties of magnesium alloys F, J, M and O.

*See text.

elongation measured on the specimen after static rupture is questionable. This factor was mentioned earlier in this section, where it was pointed out that an elongation of about 7 or 8 percent could be considered as the maximum elongation taking place before the appearance of the cracks. If this is taken to be the case, there is practically no difference between the average dynamic and the average static percentage elongations.

In those tests on alloy O with specimen of type B for which the elongation was very low, it was impossible to obtain an accurate indication of the energy absorbed. For such small elongation the duration of the diagram is extremely short. Had the horizontal scale been increased on the oscillograph this determination might have been possible. In view of this fact only the results of tests for which the energy could be measured were used to compute the average dynamic elongation. This procedure was adopted to prevent any inconsistency between the average dynamic energy and the average elongation. If, however, all the results of the dynamic tests are taken into consideration, the average dynamic elongation is only 2.6 percent, which indicates a decrease of 10 percent in comparison with the static value. It is also probable that if energy measurements could have been obtained for all the O specimens tested, the average dynamic energy would have been about the same as the static value. The energy absorbed before rupture is, in some applications a determining factor; the order of decreasing value for the four alloys is then J, F, M and O.

5. Conclusions

The results of this investigation may be summarised as follows.

(i) The ultimate strength of all four alloys is increased by impact loading.

(ii) Under tensile impact conditions, the percentage elongation is increased by about 15 percent in alloys F and J. It is decreased to practically zero in M and O when the specimens have a fillet radius of 1/16 in. The brittleness under tensile impact loading can be avoided when a large fillet is provided.

((iii) The effect of impact velocity is to increase the energy required to produce rupture in alloys F and J by approximately 35 percent. The energy absorption capacity of alloys M and O is almost zero at all impact velocities for specimens having small radius fillets. It is practically equal to the energy absorbed under static conditions for specimens having large radius fillets.

(iv) The critical velocity of the four alloys is above 200 ft/sec.

(v) The alloys M and O are inferior for dynamic applications and are susceptible to stress concentration.

PART II. THE INFLUENCE OF VELOCITY ON THE DYNAMIC TENSILE PROPERTIES OF 24S ALUMINUM ALLOY

6. Introduction

The influence of impact velocity on the tensile properties of 17ST aluminum alloy was presented in a previous report.[8/] Part II of this report presents the results of static and dynamic tensile tests made on 24S aluminum alloy in the "T" and annealed conditions and compares them with those obtained on 17ST aluminum alloy.

7. Materials tested

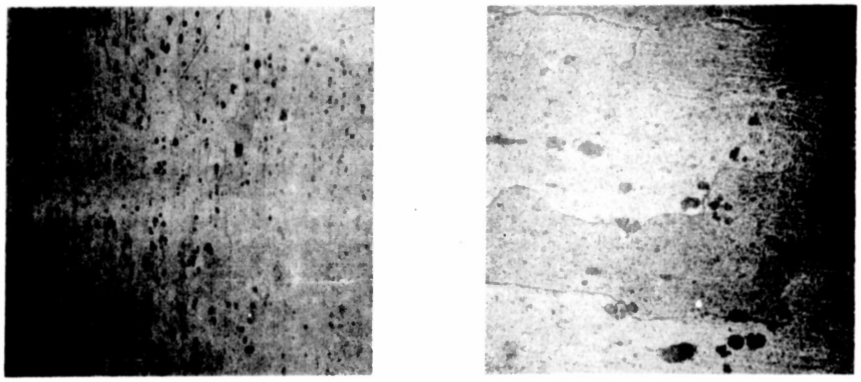
The material for these tests was procured from the Aluminum Company of America as 24ST alloy in the form of ½-in. extruded rods. The analysis of these rods is as follows: copper, 4.5 percent; manganese, 0.64 percent; magnesium, 1.55 percent; silicon, 0.20 percent; aluminum, balance. The specimens -- 8-in. gage length, 0.300 in. in diameter -- were machined from the extruded rods. One series was tested in the condition in which it was received. Another series of specimens was annealed for 20 min at 675°F and cooled in the furnace at the rate of 25°F/hr. These specimens were designated as 24S annealed.

The photomicrographs in Fig. 9 show the structure of the metal in the two different structural conditions. Two static tensile tests and dynamic tensile tests were made, following the standard procedure, at impact velocities ranging from 25 to 200 ft/sec.

8. Discussion of results

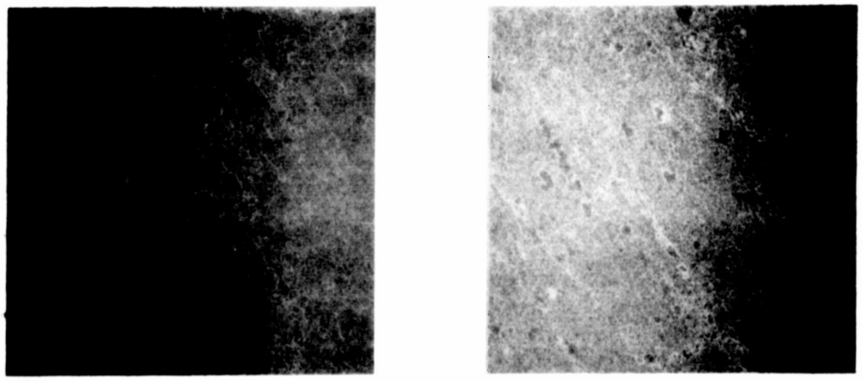
The two static stress-strain curves obtained for each type of structure, 24ST and 24S annealed, are given in Fig. 10. The numerical results of the static tests are given in Table VII. The effect of the annealing treatment was to decrease very markedly the values of all the static properties with the exception of the reduction of area, which remained practically unchanged.

8/ Ref. 2.



100 × 500 ×

24ST, etched with Kellers reagent.



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24S Annealed, etched with Kellers reagent.

Fig. 9. Photomicrographs of aluminum alloy 24S.

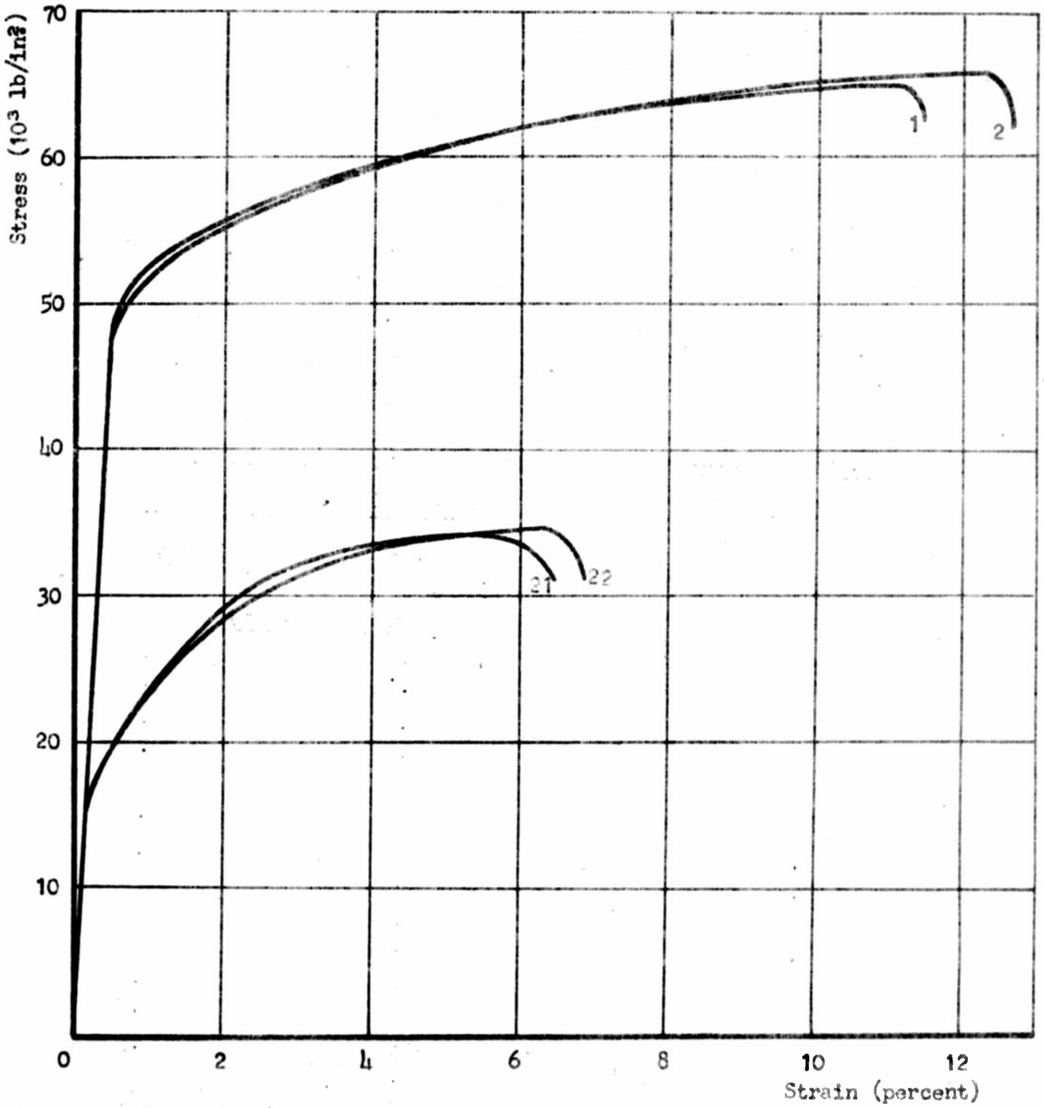

Fig. 10. Static stress-strain curves for 24 ST aluminum alloys (specimens 1 and 2) and for 24 S Annealed aluminum alloy (specimens 21 and 22).

Table VII. Results of static tests on 24S aluminum alloy.

Type of Structure	24ST		24S Annealed	
Specimen number	1	2	21	22
Ultimate strength (lb/in^2)	64 800	65 500	33 700	34 200
Proportional limit (lb/in^2)	47 500	46 500	14 000	14 000
Energy per unit volume (ft lb/in^3)	564	615	159	169
Elongation in 8 in. (percent)	10.8	11.9	6.5	6.9
Reduction of area (percent)	33	33	36	38
Hardness Rockwell A	46.4	46.3	21.1	20.8
Theoretical critical velocity (ft/sec)	280	301	162	187
Experimental critical velocity (ft/sec)	>200		>200	

Table VIII. Results of dynamic tensile tests on 24ST aluminum alloy.

Specimen No.	Impact Velocity (ft/sec)	Ultimate Strength (lb/in^2)	Energy per Unit Volume (ft lb/in^3)	Elongation in 8 in. (percent)	Reduction of Area (percent)	Hardness Rockwell A
3	25.0	68 000	610	11.7	35	46.3
9	25.0	68 800	588	11.1	37	46.4
10	49.9	67 000	656	12.3	37	46.7
4	50.0	67 500	630	11.7	34	46.2
11	74.5	67 500	592	11.0	37	43.3
5	75.1	66 700	640	12.3	38	46.7
12	99.5	69 000	760	13.5	36	45.7
6	100.5	66 900	840	15.2	39	46.3
7	125.0	71 000	826	14.1	38	46.3
13	126.0	70 400	875	15.3	37 & 35*	46.5
8	149.3	72 000	862	14.0	37	46.8
14	149.5	66 800	752	13.6	31	44.8
16	175.0	68 200	730	13.2	38	46.3
15	175.5	67 500	765	13.9	38	44.2
18	198.8	71 000	955	16.8	45	46.5
17	200.0	70 000	905	15.9	38 & 34*	46.1
					Average	46.0

*Double rupture.

Table IX. Results of dynamic tensile tests on 24S annealed aluminum alloy.

Specimen No.	Impact Velocity (ft/sec)	Ultimate Strength (lb/in²)	Energy per Unit Volume (ft lb/in³)	Elongation in 8 in. (percent)	Reduction of Area (percent)	Hardness Rockwell A
21	0	33 700	159	6.5	36	21.1
22	0	34 200	169	6.9	38	20.8
24	24.7	41 500	273	8.6	47	22.4
23	25.6	42 200	298	9.7	43	23.4
26	49.7	42 800	254	8.1	44	22.9
25	50.1	45 400	320	9.3	43	22.6
27	75.0	45 100	328	9.1	40	18.2
28	75.4	44 800	380	10.8	42	23.1
30	100.0	47 200	290	8.2	50	22.4
29	101.0	44 800	350	10.1	48	21.4
31	124.9	47 300	380	10.8	45	22.2
32	125.2	46 400	334	9.6	46	22.5
34	150.0	43 000	380	10.2	43	22.2
33	150.0	46 100	320	9.5	43	22.6
36	172.8	44 000	350	10.8	45	22.0
35	174.5	---	---	11.2	40	22.6
37	176.3	43 100	295	9.7	51	20.7
38	200.0	47 500	280	8.3	43	21.9
39	202.0	42 500	450	15.1	50 & 48*	20.9
					Average	21.9

*Double rupture.

Table X. Comparison between average static and average dynamic values for 24S and 17ST aluminum.

Alloy Designation	17ST	24ST	24S Annealed
Average hardness (Rockwell A)	42.5	46.0	21.9
Static proportional limit (lb/in²)	38 500	47 000	14 000
Ultimate strength (lb/in²)			
Static	59 900	65 150	33 950
Dynamic	68 800	68 600	44 980
Increase (percent)	7	5	33
Elongation in 8 in. (percent)			
Static	14.2	11.3	6.7
Dynamic	17.0	13.5	9.9
Increase (percent)	20	19	48
Energy per unit volume (ft lb/in³)			
Static	594	589	164
Dynamic	854	749	337
Increase (percent)	44	27	105
Reduction of Area (percent)			
Static	41	33	37
Dynamic	41	37	45

The results of the dynamic tensile tests are given in Tables VIII and IX and the curves of ultimate strength, percentage elongation and energy per unit volume required to rupture the specimen, each versus impact velocity, are presented in Fig. 11. The average dynamic properties are compared with the static properties in Table X. The properties of 17ST aluminum alloy previously reported are also given for comparison. A graphical representation of this comparison may be seen in Fig. 12.

The increase of tensile properties effected by dynamic conditions is practically the same for the two alloys 24ST and 17ST. Dynamic loading has a much greater influence on the tensile properties of 24S (annealed) than on the other two alloys. For example, the energy per unit volume required to fracture the annealed 24S alloy is increased by as much as 105 percent while the increase with the 17ST and 24ST alloys is only 44 percent and 27 percent, respectively. Even with this improvement, the dynamic properties of the annealed 24S alloy are still inferior to those of the 17ST and 24ST alloys while the computed critical velocity of the annealed 24S alloy is less than 200 ft/sec, experimentally it is found to be above 200 ft/sec.

The fact that the theoretical value of the critical velocity is smaller in some cases than the observed value has been reported before for other metals.[9/] This discrepancy has been attributed to the difference between the dynamic and the static stress-strain curves.

9. Conclusions

From this investigation it may be concluded that the energy absorbing capacity of annealed 24S aluminum alloy is greatly inferior to that of the same alloy in the "T" condition under both static and dynamic conditions. The critical velocity of this alloy in both structural conditions is above 200 ft/sec. It may be concluded further that the dynamic tensile properties of 24ST aluminum alloy do not differ appreciably from those of 17ST aluminum alloy. If there is any difference it is slightly in favor of the 17ST alloy in so far as percentage elongation and energy absorbing capacity are concerned.

9/ Ref. 1.

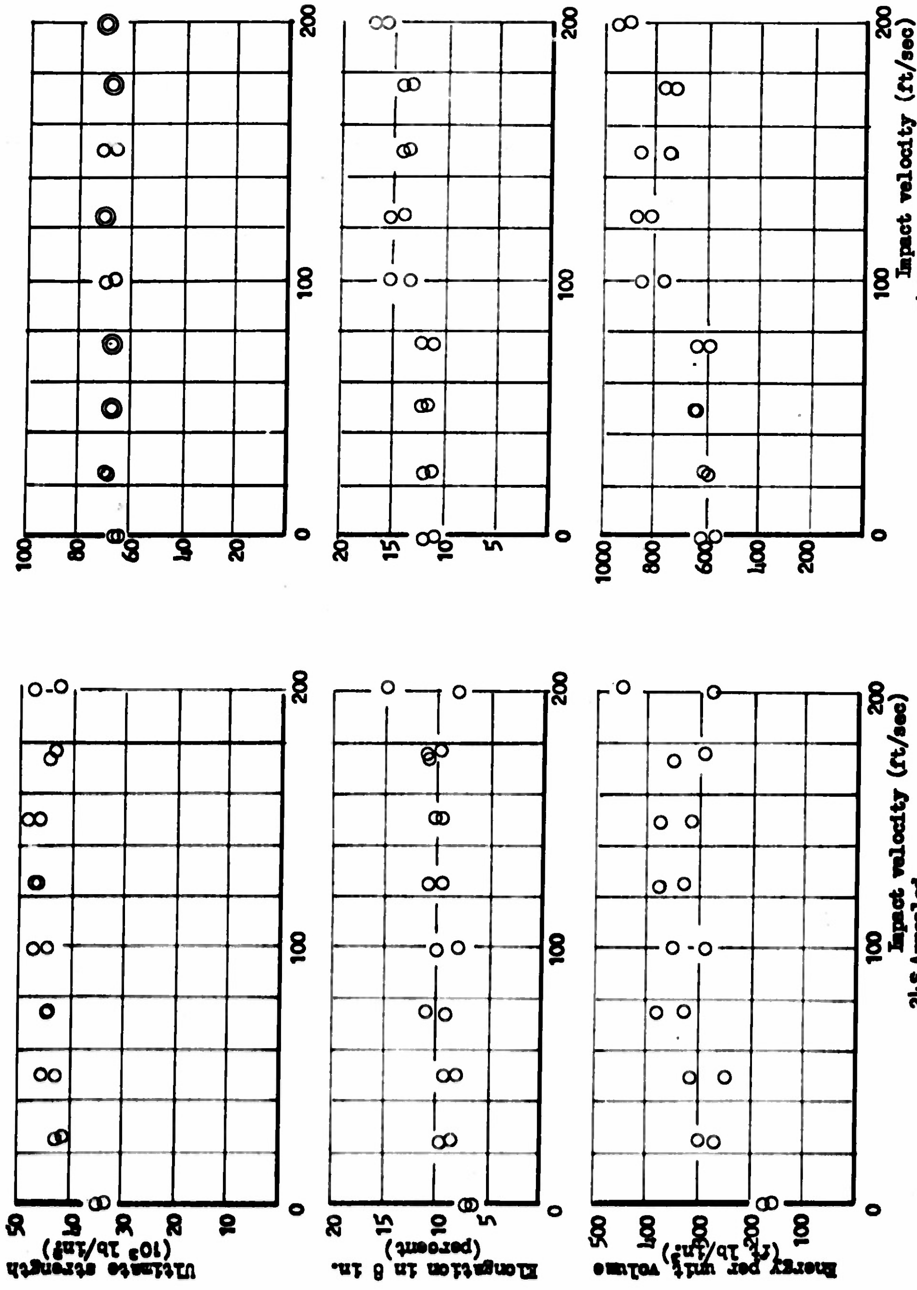

Fig. 11. Ultimate strength, percentage elongation, and specific energy, each versus impact velocity, for 24S aluminum alloys.

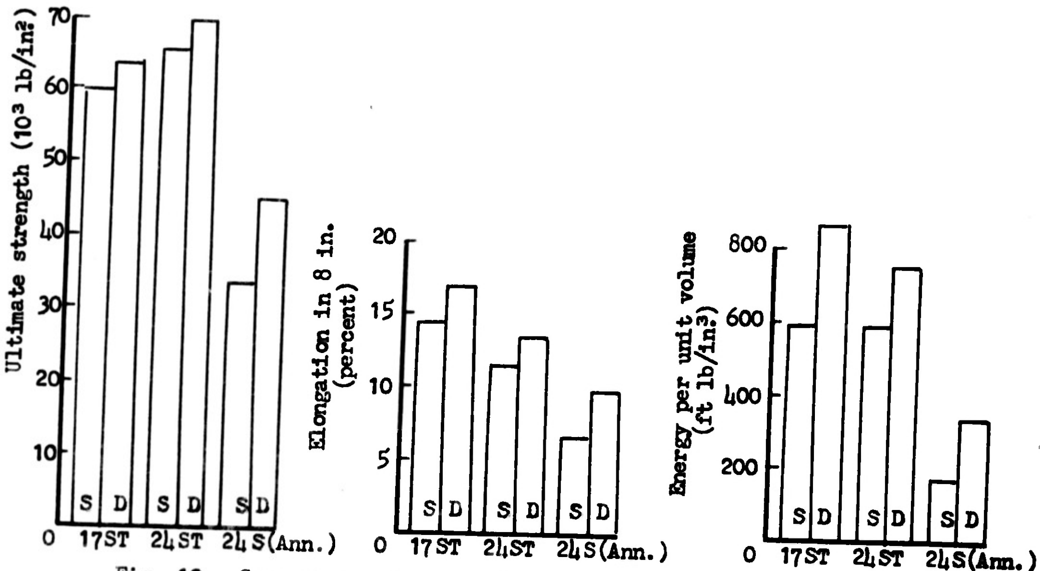

Fig. 12. Comparison of static S and dynamic D properties of aluminum alloys 17ST, 24ST and 24S (annealed).

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TITLE: The Influence of Impact Velocity on the Tensile Properties of Four Magnesium Alloys and 24 S Aluminum Alloy

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ABSTRACT:

Investigations were made to determine the influence of impact velocity on the tensile properties of metals and alloys. It was found that Dow Metal M-HTA and 0-1-HTA are susceptible to embrittlement by stress concentration. The energy per unit volume required to fracture these two alloys dynamically was about the same as statically when a fillet of 5 in. radius was used. The energy to fracture Dow Metal FS-1-HTA and J-1-HTA in specimens with 1/16 in. radius fillet is higher dynamically then statically. The critical velocity of each of the four alloys is greater than 200 ft/sec. Static and dynamic tensile tests were conducted on a 24S aluminum alloy in the "T" and annealed conditions. The tensile properties of this alloy in both structural conditions are larger dynamically than statically. The values of these properties are lower for the annealed alloy and the critical velocity is greater than 200 ft/sec for both structures.

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